SWIRE: The SIRTF Wide-area InfraRed Extragalactic Survey

Carol J. Lonsdale

IPAC, California Institute of Technology and Jet Propulsion Laborartory

Pasadena, CA, USA

Abstract

SWIRE is a wide-area, high latitude, imaging survey to be undertaken with SIRTF to trace the evolution of dusty, star-forming galaxies, evolved stellar populations, and AGN, as a function of environment from z~2.5 to the current epoch. Building on ISO's heritage, SWIRE complements smaller, deeper SIRTF GTO (Guaranteed Time Observer) surveys, and paves the way for the Herschel (FIRST) observatory to be launched in 2007. With MIPS 5σ sensitivities of 0.45/2.75/17.5 mJy at 24/70/160μm, and 7.3/9.7/27.5/32.5 μJy at 3.6/4.5/5.8/8.0μm for 70□, SWIRE will result in highly uniform source catalogs and high-resolution, calibrated images, providing an unprecedented view of the evolution of galaxies, structure, and AGN. Extensive modeling suggests that the Legacy Extragalactic Catalog may contain in excess of 2 million IR-selected galaxies dominated by (1) luminous infrared galaxies, $L_{fir}>10^{11}$ L_{sun}, up to 40,000 with z > 2; (2) ~10^6 early-type galaxies (~4×10^5 with z>2); (3)~30,000 classical AGN and as many as 250,000 dust-obscured QSO/AGN.

The large area of the 7 survey fields will allow examination of the evolution of clustering on co-movingscales up to several hundred Mpc, and will, for the first time, directly address the clustering of evolved stellar systems (IRAC) *vs* active star-forming systems and AGN (MIPS) in the same volume. These fields will have extensive data at other wavebands, particularly in the optical, near-IR and X-ray; further ground-based imaging will be undertaken at NOAO and other observatories for the entire survey in BVI with a smaller area in the near-IR, providing a comprehensive photometric database for examination of all aspects of galaxy, AGN, and structure evolution for 0.5<z<2.5. SWIRE Legacy data will be will be combined with a wide range of X-ray, optical, infrared, submm and radio data, largely available through IPAC's Infrared Science Archive (IRSA).

Introduction: Science Questions Addressed by SWIRE

The goal of the SWIRE Legacy Survey is to enable fundamental studies of galaxies and structure, and the importance of starbursts and active galactic nuclei (AGN), in the key redshift range, 0.5<z<2.5, encompassing most of the history of the Universe, during which there was a dramatic decline in the integrated energy density from galaxies (Figure1). The specific goal is to understand in detail, over lookback times $0<t_l<10$ Gyr (ΛCDM cosmology - H_o=75; Ω_m=0.3; Ω_Λ=0.7):

- The evolution of both actively star-forming and passively-evolving galaxies to determine the history of galaxy formation (including the global Star Formation History - SFH), in the context of cosmic structure formation and galaxy environment.

- The spatial distribution and clustering of evolved galaxies, starbursts, and AGN, relative to that of dark matter, and the evolution of their clustering.
- The evolutionary relationship between galaxies and AGN, and the contribution of AGN accretion energy to the cosmic backgrounds, relative to that from nucleosynthesis.

The survey will also be invaluable for Galactic studies – low mass stars and brown dwarfs, for example – and also some solar system science. In addition, the unprecedented volume of 'discovery space' provides a tremendous opportunity for the community to discover new classes of object, both Galactic and extragalactic, including rare sources at the 1-in-10^{4-6} level.

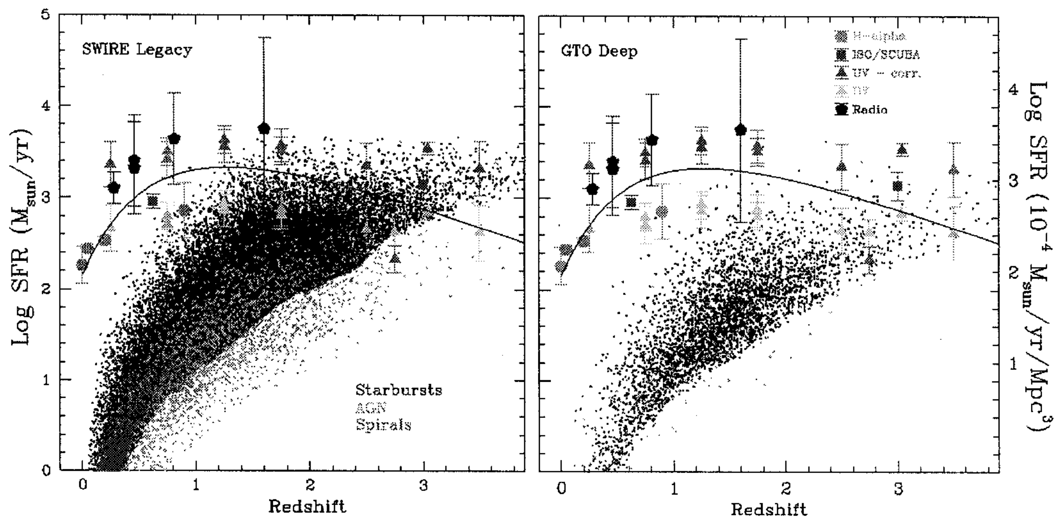


Figure 1: *Model Star Formation Rates (SFR) (Xu et al.) showing (left) 1-in-10 model SWIRE galaxies and (right) 1-in-10 model GTO Deep Survey galaxies, compared to the integrated Star Formation History (SFH) (righthand axis; following Somerville et al). [AGN SFRs reflect their 70μm luminosity if starburst dominated.] The curve is Rowan-Robinson's (2000, MNRAS, submitted) model for IR galaxies. [Note that the model SFRs are flux-limited distributions, not SFRs /unit volume, so are not expected to fit the shape of the global SFH.]* ***SWIRE will far exceed*** *accurate determination of the 0.5<z<2.5 global SFH by resolving it at the galaxy level as a function of environment.* ***Furthermore, SWIRE will detect many more z>3 galaxies than the GTO Deep survey****, if objects with SFR>350M_{sun}/yr exist there.*

The SIRTF MIPS bands are superlative, by design, for studies of the evolution of dusty star-forming galaxies and AGN. SIRTF provides an unprecedented opportunity to determine the star formation history of the Universe, as recently dramatically underscored by:

1. The COBE detections of the cosmic infrared background (CIB; see Lonsdale 1999 in *Astrophysics with Infrared Surveys*, p24, for a review) which demonstrate that at least 40% of the luminous energy density of the Universe emerges between 10μm and 1mm.
2. The dramatic evolution between nearby luminous far-infrared galaxies (LIRGs and ULIRGs), which represent only ~1% of the *local* luminous energy density (Soifer & Neugebauer 1991,AJ,101,354), and the 850μm SCUBA sources at 1 ≤ z ≤ 6, which may dominate the energy budget of the high-redshift Universe (eg. Hughes *et al.* 1999, X Recontres de Blois: astro-ph/9810273).

Thus, no matter how well optical and UV light traces baryonic matter, *and* may be reliably corrected for extinction, there is ***no substitute for direct observations and detailed study in the***

IR where the major fraction of all the luminous energy ever emitted resides. ISO has made an important start to addressing these issues but was limited in both sample size and depth. SCUBA takes excellent advantage of the favorable submillimeter k-correction at z>1, but only maps at ~1 source/10 hrs. Now SIRTF ($3<\lambda<180\mu m$), together with Herschel/FIRST ($80<\lambda<670\mu m$; 2007 launch), stand poised to directly measure the bolometric energy density of the Universe. A wide area coordinated survey with both missions is essential if one of the primary goals of both missions – to fully characterize the far-infrared/submm populations of the universe – is to be met.

IRAC is perfectly designed to study spheroids over redshifts 0.5<z<3.5. Moreover the 4 IRAC bands alone provide an excellent photometric redshift indicator for spheroids over these redshifts from the H^- 1.6μm feature (Simpson & Eisenhardt 1999,PASP,111,691), allowing a full census of $\sim 10^6$ galaxies in the SWIRE survey volume, virtually unaffected by extinction (compared, for example, to K-band which samples the restframe blue light at the highest redshifts).

Extensive ground-based campaigns have slowly opened up the z<1 universe, showing that luminous galaxies (L>~L*), both spheroids and disks, have changed little since z~1 (Ellis 2000, astroph/9910246; Simard *et al.* 1999,ApJ,519,565). UV/B drop-out techniques and new submillimeter observations, however, have revealed substantial numbers of z>2.5 systems (hundreds of Lyman Break Galaxies (LBGs); tens of submm sources), many apparently having substantial star formation rates. **Yet in the 1<z<2.5 "desert" we know very little,** even though this may be the critical redshift range where much evolution – perhaps most spheroid formation – occurred, followed by dramatic decline in energy density since z~1 (Lilly *et al.*1996,ApJ,469,L1). We know nothing about cluster evolution beyond z>1. SWIRE is uniquely suited to populating this crucial redshift interval with up to $\sim 2\times 10^6$ galaxies, both dusty star-forming systems & AGN (MIPS), and spheroids dominated by older stars (IRAC).

Both the spheroids sampled by IRAC and the starbursts & AGN sampled by MIPS are expected to be strongly affected by the underlying dark matter density field, the inter-galactic medium, and the local galaxy density environment. The local Universe E/S0 systems are classically associated with overdense regions, while the star-forming Lyman Break Galaxies (LBGs) at z~3, which might be their progenitors, also show a strong clustering signal. The z~1 very red "ERO" population, debated as old red spheroids vs. younger dust-reddened systems, are also highly clustered (Daddi *et al.* 2000, A&A:astroph/0005581). Hierarchical models for galaxy formation predict earlier assembly of E/S0s in high density environments than the "field", which seems to be borne out by observation (Ellis 2000). **Thus a study of galaxy history is seriously compromised if not undertaken in the context of environment**. The largest known local structures have volumes of order 10^6 Mpc^3 (100 Mpc linear size); SWIRE will sample several hundred >100Mpc co-moving volumes, 0.5<z<2.5 (Figure 2) in 7 separate target fields, enough to overcome cosmic variance uncertainties.

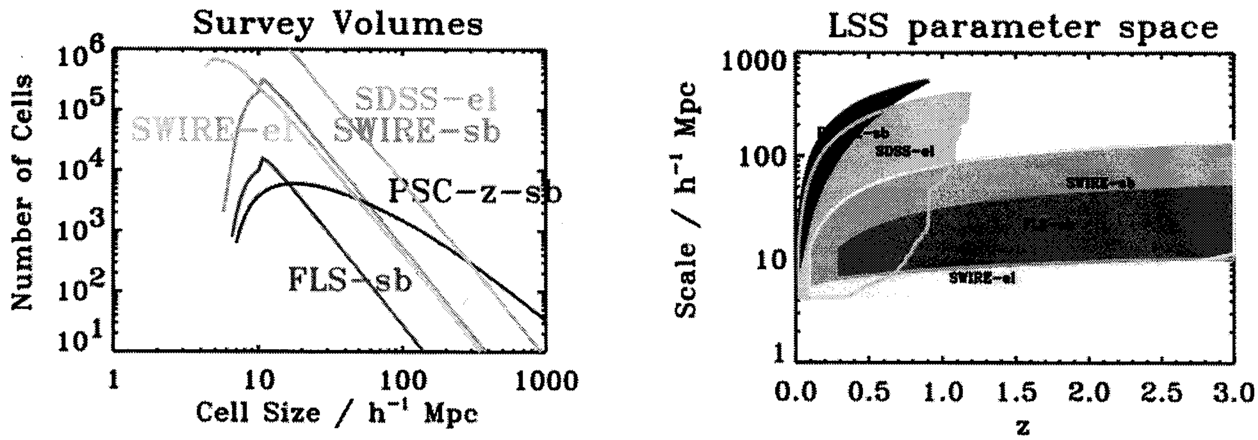


Figure 2: *SWIRE volumes for starbursts and spheroids compared to the* **FLS**, *the* **IRAS PSC-z survey** *and the Sloan survey (we have used a conservative non-Λ, Ω=1 cosmology in these figures to illustrate lower limits to the volume coverage).*

Galaxy Formation and Evolution; An IR Perspective from Global Scales to Galaxies

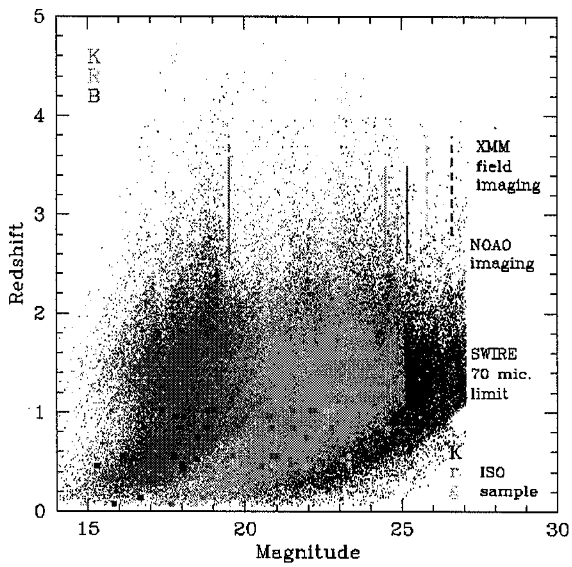
The two most fundamental quests of modern cosmology are: (1) the nature of the Universe itself (the value of the cosmological parameters, the nature of the dark matter, etc.); and (2) the origin of the Hubble sequence of galaxies. The SWIRE survey focuses on the astrophysics of galaxy formation and evolution, and also indirectly address the cosmological model. Recent studies of LBGs have shown that the clustering properties at moderate to high redshift cannot be used as a cosmological tool unless one understands where galaxies form and how they evolve relative to the underlying distribution of dark matter: cosmology and galaxy formation cannot be understood independently (Giavalisco *et al* 1998, ApJ,503,534). This consideration drives SWIRE's (1) large area sensitivity to structures up to >150 Mpc at all z; (2) complementary IRAC and MIPS volume coverage, and (3) selection of fields with substantial existing/planned data at other wavelengths.

The Global Star Formation History

The enormous advances in technology over the last decade have moved us from the era of single-band number counts probing only the z<1 Universe, to global studies of the history of the Universal energy density from the present to z >3 (Madau *et al.* 1996,MNRAS,283,1388), both by detection of very high-redshift galaxies and by detection of integrated extragalactic backgrounds. A picture emerges in which the global star formation history (SFH) was higher by as much as an order of magnitude at z~1 ($t_{lookback}$~ 7 Gyr) than at the present epoch. It is uncertain how far beyond z~2 the SFH remains flat before declining as the first epoch of galaxy formation is approached (Steidel *et al.* 1999, ApJ, 519, 1; Lanzetta 2000, BAAS 196,560). It is also unclear what fraction of the total energy is detected by UV/optical techniques; the average extinction of the UVO light for the LBGs, is estimated to be a factor of ~5 (Meurer *et al.* 1999, ApJ,521,64) but this is based on very sparse UV data for local, modest luminosity, systems; moreover some starbursting galaxies, if similar to local ULIRGs, may be obscured enough to be omitted from UVO-selected samples completely.

The first major goal for SWIRE is to determine directly the integrated energy density of the Universe contributed by resolved sources for 3<λ<180μm, over the range 0.5<z<~2.5. The importance of SWIRE is that it can connect the high z Universe of the LBGs and the SCUBA sources to the present day Universe where the global star formation rate is 5-10 times lower than its peak at z>1 (Figure 1). Locally, LIRGs and ULIRGs represent only ~1% of the local luminous energy density of the Universe, but at $1 \leq z \leq 6$ the 850μm-selected population may dominate the total energy density. What happens in the crucial redshift range 0.5<z<2.5, which accounts for most of the time since the Big Bang?

The first important SWIRE result is expected directly from the 24μm number counts (Fig. 3):



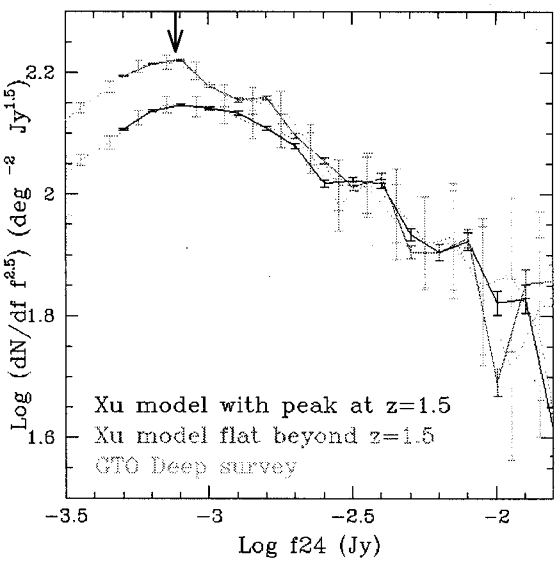


Figure 3 Left: *Predicted BRK magnitude distributions compared to observations (solid circles; Cohen et al. 2000, ApJ,538, 29; Hogg et al. 2000,ApJS 127,1) for the ISO 15μm sample of Aussel et al. (1999, A&A 342, 313). Our planned optical-NIR imaging limits (5σ; see section A.2.9) are shown as thick vertical bars: KPNO&CTIO SWIRE data - solid; ongoing XMM-LSS field - dashed.* **Right**: *As the 7.7μm Polycyclic Aromatic Hydrcarbon (PAH) feature redshifts into the 24μm filter, it produces features in the predicted $f_{24\mu m}$<2mJy counts (arrow) if the IR-measured SFH remains high beyond z~1.5. The GTO Deep survey may have difficulty detecting them (green Poisson error bars); SWIRE may not only detect but map the $N(f_{24})$ PAH peak (red error bars). Poisson noise also affects the small GTO Deep fields badly at 100 mJy.*

Census of Late-Type Stars

SWIRE/IRAC can address the fraction of baryonic matter formed into stars as a function of redshift. Hierarchical structure formation is a bottom-up process with massive halos coalescing from smaller ones, followed by the collapse of the baryonic matter inside the halos to form galaxies. This is in contrast to "monolithic collapse/passive evolution" (Eggen *et al.* 1962, ApJ,136,748), which prescribes rapid collapse and massive starbursts at high redshifts. An important discriminant between these scenarios is the fraction of baryonic mass formed into stars as a function of redshift (Renzini 1998, *The Young Universe,* p298). The GTO deep IRAC surveys have insufficient volume to address this question for z<1.

For evolved stellar systems it is essential to distinguish between the formation of stars and the assembly of galaxies: ellipticals and bulges may be assembled at relatively late epochs but their stars may have formed much earlier in smaller systems that later merged (Illingworth 1999, ApSS, 269, 165). Thus it is vital that SIRTF/IRAC sample a wide redshift range with adequate statistics to bridge the gap between z>2.5 LBGs and z<0.5 "local" populations.

The Importance of Clustering and Galaxy Environment

SIRTF is uniquely suited to address a fundamentally important question: is there a relative bias between evolved stellar systems (which will dominate the IRAC images) compared to active star forming systems (which will dominate the MIPS bands), and how does it evolve with lookback time? The importance of local density to the star-forming and morphological history of galaxies has been known since the discovery of the morphology-density relation in local clusters (Dressler 1980, ApJ, 236, 351) and the Butcher-Oemler (1978, ApJ, 226, 559) effect (an increased fraction of blue cluster members at z~0.4). In the local Universe IRAS galaxies (spirals and starbursts) are less clustered than early-type systems (Saunders *et al.* 1992, MNRAS, 258, 134). Recent ISO results in Abell 1689 (z=0.18; Fadda *et al.* 2000, A&A: astro-ph/0007437) show an excess of 15μm-bright galaxies compared to local clusters (an IR Butcher-Oemler effect); moreover they lie preferentially in the cluster periphery, where they delineate the current region of star-formation/AGN activity. The low radio luminosity-selected cluster galaxy population fraction was also 6-8 times higher ~5 Gyr (Morrison *et al.* 2000, ApJ, in press), who speculate that large-scale-structure development (cluster-cluster mergers) may trigger significant star formation in several lower redshift clusters as well. Currently, CDM theories might predict the most active star formation in the loose groups, as is observed (Hashimoto *et al.* 1998, ApJ, 499, 589).

With respect to evolved stellar systems, the SWIRE data can be used to address directly the relative ages of cluster *vs* "field" spheroids: did rich cluster members form their stars and assemble into today's E/S0 systems significantly earlier than spheroids found in lower density environments, as predicted by hierarchical galaxy formation models? The extensive SWIRE IRAC survey will generate a sample which can be used to determine the environment of early type systems as a function of redshift, stellar age, metallicity and mass, and with which to undertake studies of stellar populations, stellar age dispersions, and dynamics of spheroids in a range of environments (clusters, groups, filaments, "field") as a function of redshift.

The significance of environmental issues for structure growth and galaxy formation is difficult to assess because they have been demonstrated only on the small scales of clusters where the astrophysical processes governing galaxy evolution are highly nonlinear. IRAS sources may follow a nonlinear correlation out to ~30 h^{-1}Mpc, tracing the dark matter field better than optically-selected galaxies (Saunders *et al.* 1992). SWIRE can study this issue on the >100Mpc scales of the largest known structures (and where the power spectrum is expected to be linear) to z~2. At z~2 will the luminous SWIRE starbursts trace filaments, indicating the most prominent environments of active galaxy formation, like strings of Christmas lights? How does Figure 1 resolve into 3D space and epoch?

SWIRE will provide a unique resource for revealing how the dynamical and star-formation histories of galaxies map into their observed photometric, spectroscopic and morphological histories, and how all these depend on the evolution of the environment, ultimately leading back to the cosmological model (Seljak 2000, Phys. Rev. D., in press: astroph/0001493). This will be the first time these questions have been systematically addressed beyond z~0.1.

Of prime importance for these clustering/environmental studies is the XMM-LSS target field (http://vela.astro.ulg.ac.be/themes/spatial/xmm/LSS/index_e.html). For this 10□ SWIRE field, the community will have access to complete mapping by XMM at 0.1-10kev, a dataset of

unparalleled importance for the detection of clusters and AGN. The XMM survey is expected to detect the entire group population to z~0.5, and the massive cluster population to z~2. The SWIRE-XMM data will provide a powerful probe of galaxy SFRs as a function of cluster potential, and effects of star formation and AGN on the ICM density and enrichment (through superwinds, for example). MIPS will be sensitive to SFRs as low as 10 M_{sun}/yr at z=1 (Figure 1), providing a sensitive diagnostic for resolving the fate of infalling gas in cooling flow clusters. Hard X-ray survey data of such a large area are unlikely to be repeatable for many years. Moreover, an intensive campaign of very deep UV, optical, NIR and radio imaging is planned for the entire XMM-LSS field.

The Astrophysics of Galaxy Formation and Evolution

On scales of individual galaxies and pairs/groups, complex, non-linear astrophysical processes dominate - star formation, accretion, supernova feedback, *etc.* - which are extremely difficult to model accurately. What is the overall balance, as a function of redshift since z~2.5, between star formation in merger-induced, nuclear starbursts (as in local ULIRGs) and quiescent disk star-formation? Are the LBGs part of an evolving hierarchy of merging, starburst events which decline in frequency over time, and what local systems are their descendents? The power of SIRTF for addressing the astrophysics of galaxy formation and evolution is unparalleled. In combination with our optical and X-ray surveys, and coupled with the future Herschel/FIRST surveys and the deep GTO MIPS/IRAC surveys, SWIRE will determine the bolometric energy density of all galaxies on all clustering scales from ~10 to >150Mpc, up to <~1 Gyr after recombination. We also expect to resolve 40-65% of the background at 24-160μm (Xu *et al.* 2000; ApJ; astro-ph/0009220).

AGN, the Accretion Powered Energy of the Universe, and the Importance of X-rays

What is the true frequency and integrated energetics of AGN events and the total contribution of accretion power to the energy density of the Universe, in particular the CIB measured by COBE? Hard X-ray studies with ASCA, BeppoSax and Chandra, coupled with models of the X-ray Background (XRB), now confirm that many AGNs are very highly obscured, some even Compton thick, and are missing from our UV/opt/radio-selected inventories. These "missing" AGN - whether the fabled "type 2 QSOs" or not - are expected to be bright in the mid-IR to submillimeter due to dust-reradiation from the obscuring material, and may be responsible for 10-30% of the CIB (Gunn & Shanks 2000, MNRAS:astroph/9909089).

Could a large population of dust-obscured QSOs masquerade as ULIRGs? There is strong evidence for a link between the formation of black holes and galaxies (Magorrian *et al.*1998, AJ, 115, 2285), and strong observational connections between them in the local Universe (Sanders 1999, ApSS, 266, 331). ISO spectroscopy appears to disfavor the obscured QSO interpretation of ULIRGs (Genzel & Cesarsky 2000, ARAA, in press), but powerful counter-evidence comes from X-ray studies with ASCA and BeppoSax: some ULIRGs house powerful AGN, ***completely hidden*** behind column densities, $N_H > 10^{24}$, obscuring even soft X-rays and mid-IR emission (Risaliti *et al.* 2000, A&A, 357,13). There is also VLBI evidence for AGN cores in ULIRGs (Lonsdale *et al.* 1993, ApJ, 405, L9; Smith *et al.* 1998, ApJ, 492, 137). The 2MASS survey has uncovered a population of mostly type 1 red QSOs which are probably a highly incomplete sampling of the reddened tail of the known QSO population (Cutri *et al,* 2000, in press), while the FIRST radio survey is turning up significant samples of type 2 red objects with intermediate radio strength (White *et al.* 2000, ApJS, 126, 333).

SWIRE/MIPS will easily *detect* IR-loud (dust-obscured) AGN to z>2.5 (Figure 1), whether obscured by edge-on molecular tori or by large columns associated with merger-induced starbursts. SWIRE/IRAC will be much more sensitive than 2MASS to the heavily reddened population (but not those with extremely high N_H); perhaps finding >5000/□. Most low and moderate extinction AGN will be revealed through warm dust in the IRAC bands and at 24μm, though strong PAH features can confuse interpretation of broadband colors (Clavel *et al.* 2000, A&A, 357, 839; Laurent *et al.* 2000, A&A, 359, 887). The biggest difficulty will be in ***identifying the most highly obscured AGN, even in the mid-IR,*** as is the case in the local Universe. Hard X-rays are uniquely capable of penetrating all but the highest columns; thus the importance of the very large area XMM field, which combines deep surveys in the three optimum spectral regions for identification of highly obscured AGN: hard X-ray, MIPS FIR, and low-frequency radio.

Modeling

In preparation for the SWIRE project a suite of models and simulations has been developed to aid in experiment design and analysis, and to interpret the SWIRE data, including the Universal SFH and addressing, in 3D, the mid- to far-IR response to clustering and to galaxy environment.

Backward Evolution Modeling

Beginning with IRAS analysis (Hacking *et al.* 1987, ApJ, 316, L15; Lonsdale *et al.* 1989, ApJ, 358, 60; Franceschini *et al.* 1988, MNRAS, 233, 157; Rowan-Robinson *et al.* 1991, MNRAS, 247, 1; Oliver *et al.* 1992, MNRAS, 256, 150) and WIRE development (Xu *et al.* 1998, ApJ, 508, 576) team members have been world leaders in these models which employ a local luminosity function, SEDs, and an evolution prescription, evolved backwards in time to predict flux, redshift, color, etc. Three new models have been developed (Xu *et al.* 2000; Rowan-Robinson 2000, MNRAS, in press; Franceschini 2000, MNRAS:astroph/9909290), all with the critical feature of incorporating the solid-state mid-IR spectral features and their variation with environment, and of fitting the ISO and SCUBA source counts and reproducing the CIB. These models have differing predictions for SWIRE, providing useful diagnostics. They are very powerful for statistical characterization of evolution of populations, being simple, empirical, robust, and involving few free parameters.

Forward Evolution Modeling Whilst backward models can provide a **global** view of galaxy evolution, there is no prescription for addressing the astrophysics of individual galaxies and their environments. An alternative approach begins with initial conditions (usually CDM) and traces the evolution of the dark matter density field and the response of the baryons. Whilst highly successful in explaining an impressive array of observations (White 1999, ApSS, 267, 355), there are notable difficulties for CDM, such as the failure to reproduce the size and angular momentum of disks obeying the Tully-Fisher relation (Navarro & Steinmetz 2000, ApJ:astroph/0001003). Of relevance to SWIRE is the difficulty of generating galaxies at high enough redshift to account for the >100Mo/yr SFRs attributed to the z>1 SCUBA sources and for some LBGs, without introducing an additional population with unconstrained physics (eg. Guiderdoni *et al.* 1998, MNRAS, 295, 877; Somerville *et al.* 2000, MNRAS in press, astro-ph/0006364).

We have developed a simple forward evolution model to determine whether bulge and spheroid formation by mergers of gas-rich companions can explain the evolution of FIR luminosity density (Masci, Carlberg, & Lonsdale 2000, in prep). As others have concluded (Kauffmann & Haehnelt 2000, MNRAS, 311, 576) neither the steepness of the z<1 ISO 15μm N(f) nor the high SFRs of the z>1, 850μm population may be explained solely by the decrease in merger rate; an additional substantial decrease in star-formation efficiency, or other factor, is required.

Science Analysis

SWIRE will survey a large enough volume in the 1<z<2.5 "desert" to determine the integrated SFH in starbursts and the total mass of stars in massive spheroids during these epochs. Furthermore, it will have enough sources to trace N(SFR,z,environment) and N(stellar mass,z,environment) throughout this redshift range. The first results will come from estimates of population classification, redshift and luminosity using appropriate color-magnitude and color-color diagrams:

- A MIPS-IRAC (e.g. $f_{3.6\mu m}/f_{24\mu m}$ *vs* $f_{3.6\mu m}/f_{4.5\mu m}$) color-color plot segregates dusty (starburst, disk, AGN) galaxies from bulge dominated systems.
- Luminosity classification for dusty systems will be provided via the well known relation between Far-Infrared/Optical color and Far-Infrared Luminosity.
- For dusty systems the $f_{8\mu m}/f_{24\mu m}$ *vs* $f_{24\mu m}/f_{70\mu m}$ diagram is effective for segregating starburst systems, disk galaxies and AGN of moderate N_H ; furthermore this relation is a reasonable redshift indicator.
- For bulge-dominated galaxies, detected by IRAC, the $f_{3.6\mu m}/f_{4.5\mu m}$ vs $f_{5.8\mu m}/f_{8.0\mu m}$ two-color diagram will be an effective redshift predictor (Simpson & Eisenhardt 1999).

There remain degeneracies in all the above relations, particularly with respect to AGN vs Starburst population classification. This underscores the importance of X-ray data for identifying AGN candidates and is why we have emphasized X-ray fields in our survey strategy.

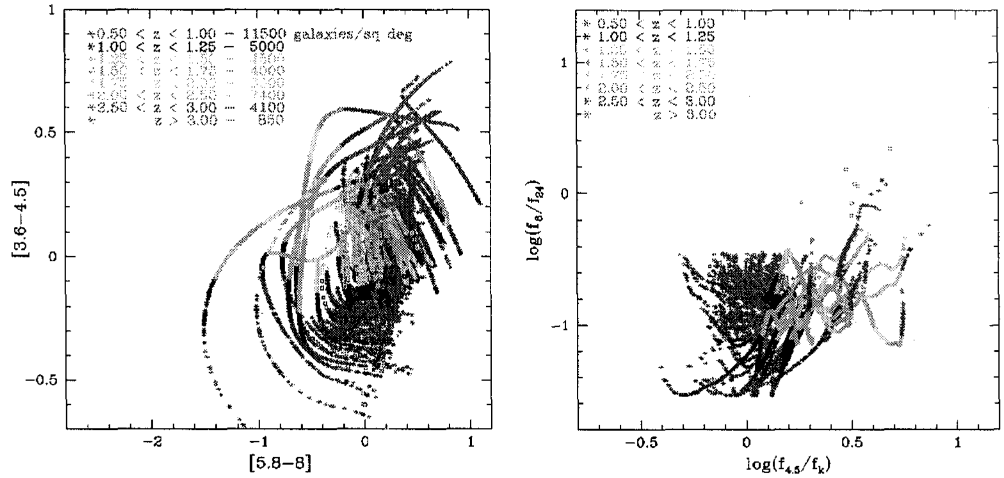


Figure 4: *Predicted SWIRE two-color diagrams (SED tracks) from Xu model: a) the IRAC 2 color photo-z diagram; b) two color K-IRAC-MIPS diagram with photo-z possibilities.*

For Large Scale Structure analysis we will focus on two topics: (1) the evolution of clustering of spheroids vs starbursts and AGN up to scales of >150 Mpc at z>0.5, well into the non-linear regime, and (2) the effect of the local environment on galaxy astrophysics.

Spatial 3-D correlations can be calculated from the photometric data without distortions caused by galaxy peculiar velocities (Baugh & Efstathiou 1994, MNRAS, 67, 323) by inverting Limber's

(1954, ApJ, 119, 655) equation, using a model redshift distribution. The 3-D power spectrum of the galaxy density distribution can be similarly estimated. We will first select samples in flux density bins, coupled with models of the selection function, luminosity and redshift distributions, to study the clustering evolution to z~2. We will also employ photometric redshifts to bin by redshift and luminosity, a technique expected to be especially successful for IRAC-selected galaxies (Figure 4). Our MIPS areas will enable measurements of the correlation function and power spectrum of star-forming galaxies and evolved galaxies on scales >150 h^{-1} Mpc ($0.5<z<2.5$), which will be compared to that of optical galaxies in the same field and of clusters at the same z to measure the bias. The results will provide the first accurate measurement of the kind for infrared galaxies at great depth and large-scale.